## BACKGROUND OF THE INVENTION

1. Field of the invention:

The present invention relates to a liquid crystal active-matrix display device which has thin film transistors (hereinafter referred to as TFTs) as addressing devices for controlling the transmittance of picture elements. More particularly, it relates to a liquid crystal active-matrix display device which has, as addressing devices, reverse stagger type TFTs whose semiconducting film is made of amorphous silicon (a-Si).

2. Description of the prior art:

Figures 3a and 3b show a conventional liquid crystal active-matrix display device in which reverse stagger type TFTs are used as addressing devices. This liquid crystal display device comprises a pair of cell substrates 120 facing each other and a liquid crystal layer 103 sealed in the gap between the pair of cell substrates 120. One of the two cell substrates 120 comprises an insulating substrate 101, gate electrodes 102, a gate insulating film 105, an a-Si (amorphous silicon) semiconducting film 106, an insulting film 107, an $n^+$-a-Si ($n^+$-amorphous silicon) contact film 108 for ohmic contact, source and drain electrodes 109, picture element electrodes 110 for display, and a protective film 111. The picture element electrodes 110 are arranged in a matrix format. An additional capacity electrode Cs parallel to the liquid crystal capacity is formed to improve ~~the~~ picture element potential-retaining characteristics and to minimize the shift in the picture element electrode potential level at the

time of the fall of the gate driving pulse resulting from the capacity between the gate electrode 102 and the drain electrode 109 (Proc. Japan Display '83, p.412 (1983) and Proc. Euro Display '84, p.145 (1984)). The additional capacity electrode Cs is obtained by forming transparent conducting film in two layers on the insulating substrate 101 with the extension of the gate insulating film 105 between the two layers for isolation from each other. The ~~the~~ first layer of the conducting film serves ~~serving~~ as a ground electrode 112 and the second layer serves as the picture element electrode 110, as shown in Figure 3b.

In the above-mentioned conventional liquid crystal display device, as mentioned above, the ground electrode 112 for providing the additional capacity Cs is made of transparent conducting film, so that the resistance of the ground electrode 112 for additional capacity Cs becomes high. This causes ~~causing~~ insufficient performance or a cross talk among the picture electrodes. The resistance of the ground electrode 112 for additional capacity Cs could be reduced by increasing the thickness or width of the ground electrode 112. However, the greater film thickness would result in a greater difference in level between the ground electrode 112 and the insulting substrate 101, which results in an increase in defects of step coverage of the gate insulating film 105 and other films on the ground electrode 112. The defects of step coverage would increase a short circuit between the ground electrode 112 and the picture element electrode 110 and increase the chance of breakage of the source electrode and other elements of each TFT to be formed

in the later process. The greater electrode width would result in the higher probability of a short circuit between the ground electrode 112 for additional capacity Cs and the picture element electrode 110, and between the ground electrode 112 and the source electrode 109; ~~, and~~ . It would also result in a larger capacity between the ground electrode 112 for additional capacity Cs and the source electrode 109 thus causing the cross talk in signals and a large load on the source driver.

In addition, the thicker or wider ground electrode 112 for additional capacity Cs, would involve a larger number of manufacturing processes, which is not favorable.

## SUMMARY OF THE INVENTION

The liquid crystal active-matrix display device of the present ~~this~~ invention, ~~which~~ overcomes the above-discussed and numerous other disadvantages and deficiencies of the prior art. It is directed toward ~~, comprises~~ a liquid crystal active-matrix display device including ~~comprising~~ thin film transistors that switch picture elements and picture element electrodes that are arranged into a matrix. The ~~; said~~ picture element electrodes are ~~being~~ connected to the ~~said~~ thin film transistors and the ~~said~~ thin film transistors are ~~being~~ disposed at intersecting points that are formed by gate electrodes and source electrodes which ~~that~~ are perpendicular to each other, are ~~and being~~ disposed on the ~~said~~ gate electrodes, and have ~~having~~ drain electrodes connected to the ~~said~~ picture element electrodes.

~~wherein~~ Further, the edge portion of each of ~~said~~ the gate electrodes overlaps the edge portion of each of ~~said~~ the picture element electrodes to form an additional capacitor; ~~said~~ The gate electrodes ~~being~~ are made of tantalum. ~~and a~~ a first insulating film of tantalum pentoxide and a second insulating film of silicon nitride are disposed between each of ~~said~~ the gate electrodes and each of ~~said~~ the picture element electrodes.

In a preferred embodiment, each of the gate electrodes includes a gate line that extends from each of ~~said~~ the gate electrodes in such a manner that it is positioned to overlap the periphery of the corresponding picture element electrode.

In a preferred embodiment, the gate electrodes function as additional-capacitor electrodes.

In a preferred embodiment, the first insulating film is formed by oxidizing the surface of each of ~~said~~ the gate electrodes.

In a preferred embodiment, the second insulating film is formed by plasma chemical vapor deposition.

Thus, the invention described herein makes the following objections possible: ~~possible the objectives of~~ (1) providing a liquid crystal active-matrix display device in which electrodes for providing additional capacity Cs are formed without increasing the number of film forming and etching processes; (2) providing a liquid crystal active-matrix display device in which additional

capacitors with a large capacity are formed at a high yield with little affect on other processes, because of the use of insulating films made of tantalum pentoxide with a high dielectric constant, even though the surface areas of the electrodes for providing the additional capacity Cs are small; and (3) providing a liquid crystal active-matrix display device in which the ~~said~~ additional capacitors improve the picture element potential-retaining characteristics and reduce the shift in the picture element electrode potential level at the time of the fall of the gate driving pulse resulting from the capacity between the gate electrodes and the drain electrodes.

## BRIEF DESCRIPTION OF THE DRAWINGS

This invention may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawings as follows:

Figures 1a to 1c are plane views showing the production process of a liquid crystal active-matrix display device of this invention.

Figure 1d is an equivalent circuit of the display device shown in Figure 1c.

Figure 2 is a sectional view showing the display device taken along line X-Y of Figure 1c.

Figure 3a is a plane view showing a conventional liquid crystal active-matrix display

device.

Figure 3b is a sectional view showing a part of the conventional display device shown in Figure 3a.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

### Example

A liquid crystal active-matrix display device of this invention that uses reverse stagger type thin film transistors (TFTs) as addressing devices generally includes ~~comprises~~, as shown in Figure 2, a pair of cell substrates 100 facing each other and liquid crystal 13 sealed in the space between the pair of cell substrates 100. One of the cell substrates 100 comprises an insulating substrate 1, gate electrodes 3, first insulating films 4, second insulating films 5, a-Si semiconducting films 6, third insulating films 7, $n^+$-a-Si semiconducting films 8, drain electrodes 9, picture element electrodes 10, and passivation films 11.

The liquid crystal active-matrix display device of this invention is manufactured as follows. As shown in Figures 1a to 1c, on an insulating substrate 1 made of glass, tantalum (Ta) is applied to a thickness of about 3000 Å by sputtering, and patternized by photolithography to form gate electrodes 3. These ~~which~~ also function as additional-capacitor electrodes, at specified pitches on the same plane. Then, the Ta surface of each of the gate electrodes or additional-capacitor electrodes 3 is oxidized by anodic oxidation to form a first insulating film 4 of tantalum pentoxide

$Ta_2O_5$ with a thickness of about 2000 Å. $Ta_2O_5$ presents a high dielectric constant, and is suitable for high capacity. Then, a second insulating film 5 with a thickness of about 2000 Å of silicon nitride SiNx is formed by plasma chemical vapor deposition over the entire surface of the substrate 1 so as to insulate the gate electrodes 3 from each other. Then, an a-Si film with a thickness of about 300 Å and an SiNx film with a thickness of about 2000 Å are successively formed over the entire surface of the substrate 1 and patternized by photolithography to form a first semiconducting film 6 of a-Si, which functions as a semiconducting film of TFTs, and a third insulating film 7 of SiNx on the ~~said~~ semiconducting film 6. Then, an $n^+$-a-Si film with a thickness of about 400 Å is formed by plasma chemical vapor deposition and patternized by photolithography to form a second semiconducting film 8. Thereafter, a metal film of Ti, Mo, W, or the like, that has a high melting point, is formed with a thickness of about 3000 Å by sputtering or electron-beam deposition and patternized by photolithography to form source and drain electrodes 9. A transparent conducting film that mainly contains indium oxide is formed with a thickness of about 1000 Å by sputtering or electron-beam deposition and patternized by photolithography to form picture element electrodes 10. The edge portion of each of the picture element electrodes 10 overlaps the edge portion of each of the gate electrodes 3 through the first and second insulating films 4 and 5, thereby resulting in additional capacitors that are indicated by the hatched areas of Figure 1c.

B521

Then, an SiNx passivation film 11 with a thickness of about 5000 Å is formed to cover the insulating films 5 and 7, the semiconducting film 8 and the electrodes 9 and 10 by plasma chemical vapor deposition, thereby resulting in a liquid crystal active-matrix display device with additional capacitors.

The gate electrode that overlaps a picture element electrode, so as to function as an additional-capacitor electrode, is a gate electrode that is adjacent to the gate electrode of the TFT for driving the picture elements formed by the ~~said~~ picture element electrode.

As shown in Figure 1a, each of the gate electrodes 3 can include a gate line 30, that extends, from each of the gate electrodes 3, in such a manner that it is positioned to overlap the periphery of the corresponding picture element electrode 10.

The potential level of each of the additional-capacitor electrodes is preferably unchanged during a holding period (i.e., from the time when previous writing operation has been completed to the time when next writing operation begins). However, because the gate electrodes also function as additional-capacitor electrodes for the adjacent picture element electrode, a gate driving pulse is applied to the gate electrodes during the holding period when the adjacent picture element potential should be maintained at a certain level as determined by the writing operation. This pulse raises the ~~said~~ picture element potential level through the additional

capacitors, so that the operation point of the TFTs is shifted. The shift in the operation point of the TFTs takes place in the direction that the OFF bias of the TFTs becomes more negative, and electric charges stored in the additional capacitors do not flow out of the additional capacitors.

Although a voltage applied to the liquid crystal varies during the application of the gate driving pulse to the gate electrodes, the ratio of the gate driving pulse width to the holding period is as small as 1/the number of gate lines ~~so~~. This is so that the effect of the variation in the voltage to be applied to the liquid crystal is negligible.

The area where each of the picture element electrodes overlaps each of the gate electrodes is preferably located in a long, narrow strip fashion on the outskirts of the picture element electrodes; ~~and~~ Thus, a decrease in the opening ratio of the picture element electrodes can be minimized. This construction is effective when the liquid crystal display device is driven in a normally white mode (i.e., a mode in which the display device exhibits white when no electric field is applied and the transmittance of the liquid crystal decreases with an increase in the voltage to be applied; for example, a twisted nematic display device with polarizers arranged in a cross-fashion). In a normally white mode, light leaks from the space between each picture element electrode and each gate line or each source line, which causes difficulties in attaining high contrast, so that a shading mask should be disposed on the color filter side. To secure an

alignment margin between the TFT substrate and the color filter-sided substrate, the size of the picture element electrode is set to be larger than that of the opening formed for the shading mask in the color filter-sided substrate. Accordingly, when the additional capacitor are formed in the areas of the picture element electrodes that are positioned outside of the opening of the color filter, a decrease in the opening ratio of the display device can be minimized.

Although it is most preferable that both the gate line 30 of each of the gate electrodes 3 and the edge portion of each of the gate electrodes 3 overlap the edge portion of the corresponding picture element electrode 10, even when the edge portion of each gate electrode 3 alone overlaps the corresponding picture element electrode 10, the same effect as mentioned above can be attained.

It is understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope and spirit of this invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be construed as encompassing all the features of patentable novelty that reside in the present invention, including all features that would be treated as equivalents thereof by those skilled in the art to which this invention pertains.

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